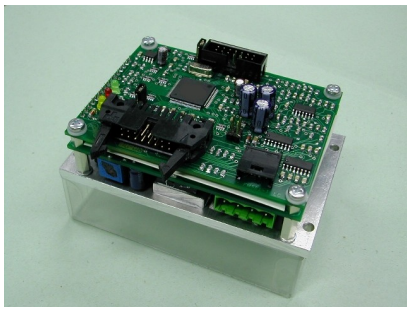
Project/product code:

FM581



Description:

Digital controlled DC-Motors amplifier

Document type:

User Manual

Reference versions:

Hardware	FM581	100V 8A	200V 5A

FRANCESCHI MARINA S.n.c.
ELETTRONICA INDUSTRIALE
Via Verga, 5 int.6
20842 Besana in B.za (MB), Italy
Tel.0362-802070 - Fax. 0362-802648
e-mail: info@franconline.com – web: www.franconline.com

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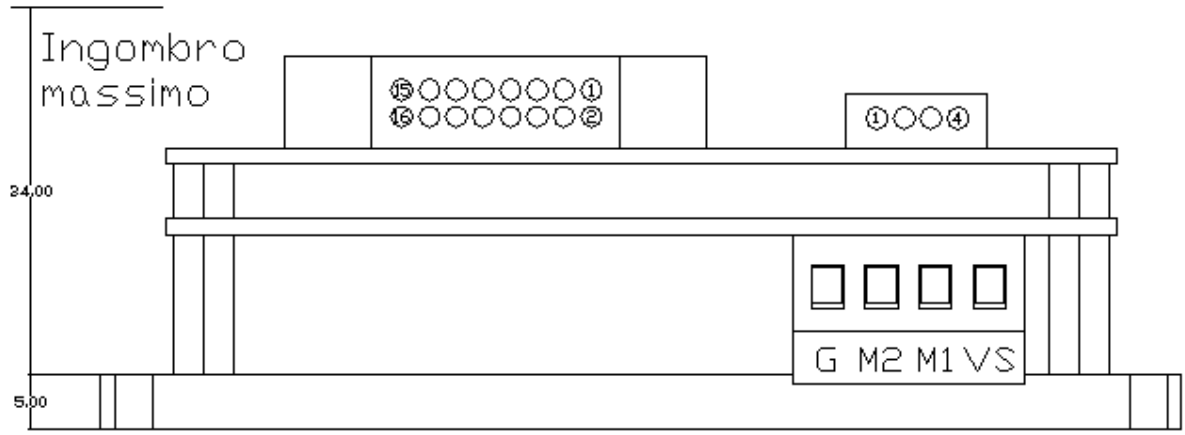
Technical specifications

FM581 size =>		100V 8A	200V 5A	
Output	Nominal current	8	5	A
	Maximum current	20	10	A
	Peak current	28	14	A
	Protection	• Supply overvoltage • Supply undervoltage • Shortcircuit • Shortcircuit to ground • Power stage overheating		
	Switching frequency	16		KHz
	PWM frequency	32		KHz
Power supply	Supply voltage (maximum)	100	195	Vdc
	Supply voltage (minimum)	20	40	Vdc
Interfaces	Control and configuration interface	Serial port RS232 19200Kbps,8E1		
	Communication protocol	ModBus, RTU mode Supported functions: 03h, 04h, 06h, 10h Slave address default: 1 (www.modbus.org)		
	Digital input	● Disable counter-clockwise rotation ● Disable clockwise rotation ● General inhibit		
	Digital output (open-drain, 24V 100mA)	● Curren limit / alarm (together) ● Drive inhibit / alarm (together)		
	Analog input	● +/-10V, main speed or current reference ● Tachometer input, with automatic offset and scale (max. 29V) ● 0-10V, nominal current limitation (abs[+/-10V])		
Control Loop features	Control loop mode	Current or Current+Speed by main input reference, with variable current limit by an auxiliary reference		
	Controller type	Current loop controller: PI Speed loop controller: PID		
	Feedback mode	For speed loop Back-EMF without external connection or with DC-tachometer.		
	Offset compesation and filtering	Automatic calibration of internal current and voltage offsets. Analog input low-pass filtered with configurable filter with the possibility to correct manually the offset.		
	Acceleration/Deceleration Ramps	from 0.1 to 30		s
Environment	Working temperature	from -10 to +50		°C
	Humidity (no condense)	from 5 to 95		%
	Protection class	IP00		
Weight Dimensions	Dimensions	100(h) x 65(l) x 39(p)		mm
	Weight	~0,2		Kg

Dimensions


Ingombro
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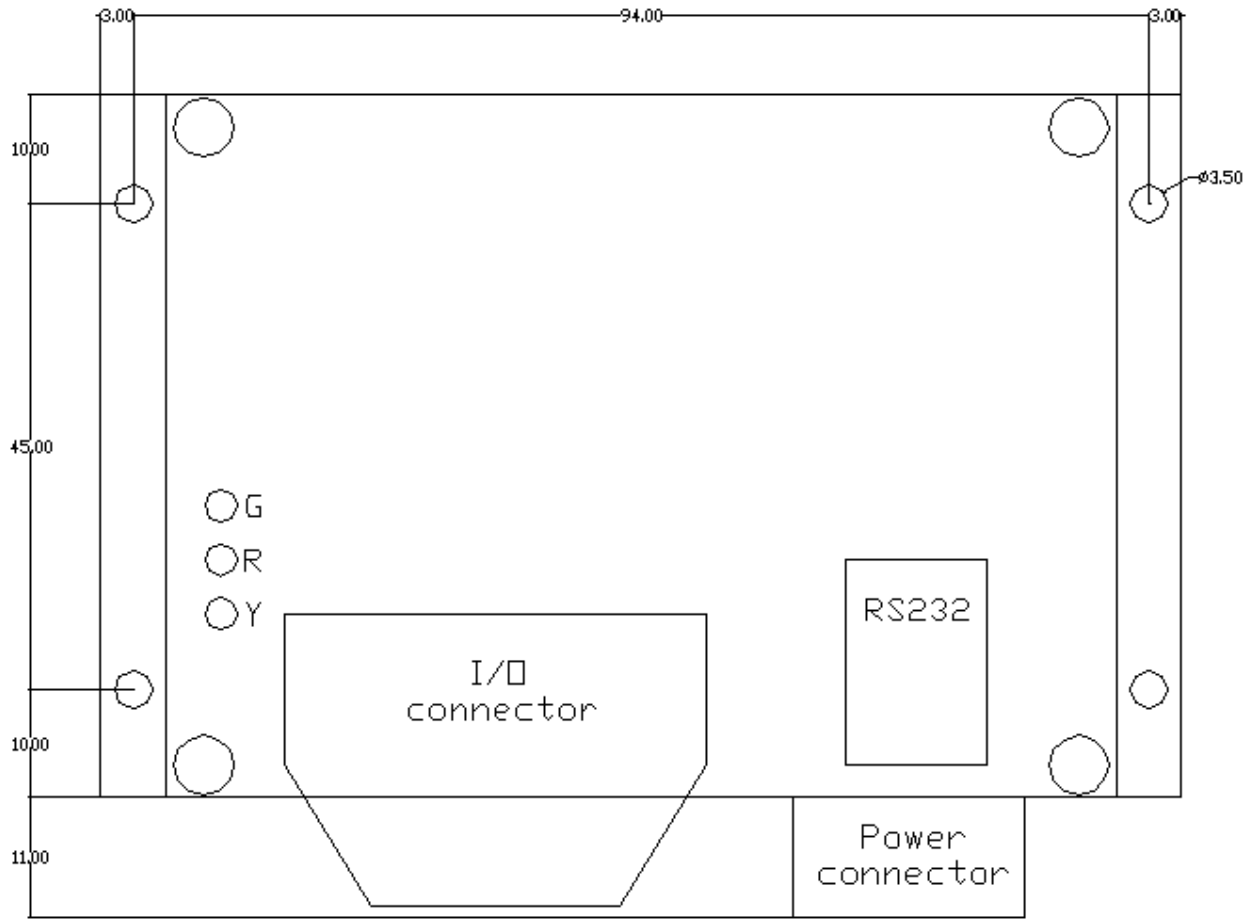
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RS232
Power
connector

Connections

Connections list			
Connector		***Description***	
J1	1	SpeedRef –	Analog input, speed/current main reference (+/-10V)
	2	SpeedRef +	
	3	Tacho –	Tachometer input (max. 29V)
	4	Tacho +	
	5	Ref –	Analog input, current limit (+/-10V)
	6	Ref +	
	7	Non connected	
	8	Input1	Clockwise rotation disable
	9	Input2	Counter-clockwise rotation disable
	10	Input3	Drive inhibit
	11	0V	Common 0V reference for the inputs
	12	Output1 (open-drain, 24V 100mA)	Digital output: drive inhibit / alarm
	13	-12V	Negative reference voltage for the analog inputs
	14	+12V	Positive reference voltage for the analog inputs
	15	Input4	Not used
	16	Output2 (open-drain, 24V 100mA)	Digital output: current limit / alarm
J2 (RS232)	1	Tx Data	Communication port RS232: 19200,8E1 Protocol ModBus, RTU mode Slave address default: 1
	2	Rx Data	
	3	GND	
	4	GND	
M1 (Power)	1	+V Supply	Main power supply, Positive (max 100V or 200V by size)
	2	M1	DC-Motor connection
	3	M2	
	4	GND	Main power supply, Ground

Digital inputs

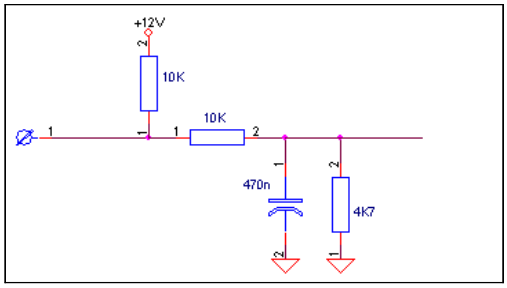
Four digital inputs are available, three with and assigned function and the fourth not used.

Input	Description
Disable CW	Disable clockwise rotation, this command leaves the motor inactive, free, without ramps or braking.
Disable CCW	Disable counter-clockwise rotation, this command leaves the motor inactive, free, without ramps or braking.
Drive inhibit	This is a general inhibit signal that disable the drive. The way to stop the motor is defined from the configuration options: freee-wheel, ramp, braking...

The configuration allows to setup the active logic state of the inputs. Input activation can be set to active-low (PNP mode) or active-high (NPN mode).

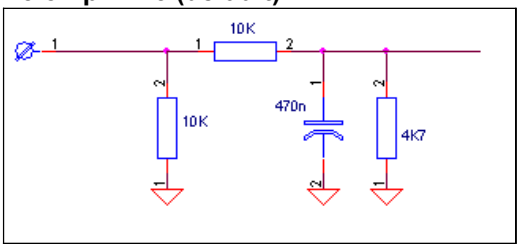
The jumper JP3 defines the input level in floating condition, by insertion of a pull-up or a pull-down resistor.

JP3 on pin 1-2:



NPN mode input, setup to activate with signals that close to 0V.

JP3 on pin 2-3 (default):



PNP mode input, setup to activate with signals that close to +12V.

For a correct operation the *active level* and the *position of JP3* must be coherent with the way the commands operate.

LED and digital outputs

The drive has 3 LED and 2 open-drain ouputs to signal its state. The open-drain outputs are designed for a maximum load of 100mA, 24V.

LED meaning:

The green LED, LD3, indicates that the power supply is connected and turned on.

LD3 (green) LD2 (red) LD1 (yellow)	Drive disabled: motor is disabled, drive is waiting for enable command.

LD3 (green) LD2 (red) LD1 (yellow)	Drive enabled: motor is enabled, drive is executing motion commands.

LD3 (green) LD2 (red) LD1 (yellow)	Drive in current limit condition: motor is still enabled, drive is trying to execute a command but the current is over the nominal value configured.

LD3 (green) LD2 (red) LD1 (yellow)	Drive alarm: motor is disabled because of a continued alarm condition. The drive will refuse any enabling request while the alarm is still present. The exact cause of the alarm can be verified using the ModBus.

Outputs meaning:

Output	Description	
OUT1	Active, close to 0V, when LD1 is on: drive inhibit.	Together, when LD1 and LD2 are both on: alarm condition.
OUT2	Active, close to 0V, when LD2 is on: current limit condition.	

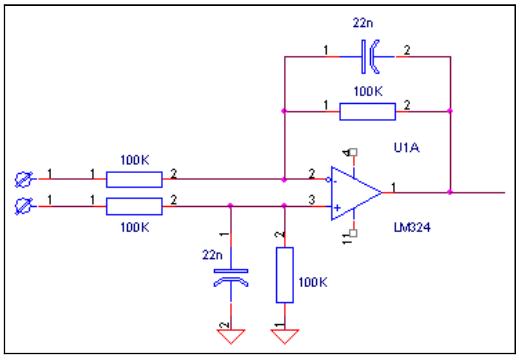
Analog inputs

Reference input (current or speed):

From this input the drive receives the main reference setpoint for speed or current.

The input signal must be between -10V and +10V. To operate with a single-ended signal place to 0V one of the poles.

The drive configuration, from ModBus, allows to correct the offset and apply a low-pass filter to this input.

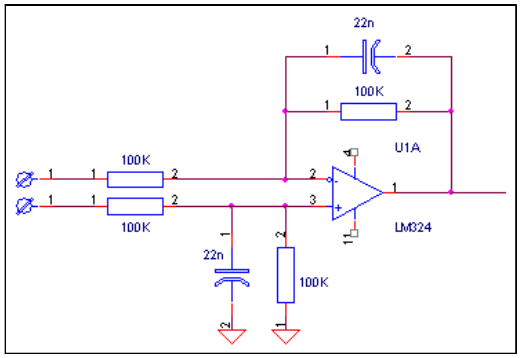


Variable current limit input:

It's possible to apply a variable current limit during the operation in speed mode. In such a situation the main reference supplies the setpoint of speed, while this auxiliary input allows to scale the limit of current regarding to the nominal value.

The control loop will accelerate the motor until the demanded speed, but always with a current under the value defined instantaneously.

The limited current could not be sufficient, in this case the drive maintains active the motor at the maximum allowed speed.



The input signal must be between -10V and +10V. To operate with a single-ended signal place to 0V one of the poles.

The drive configuration, from ModBus, allows to correct the offset of this input.

Attention: the drive uses the absolute value of the input signal to scale the nominal current value:

- +10V is the same of 100% of the nominal current, but also *-10V.*
- 0V is the same of 0% of the nominal current.

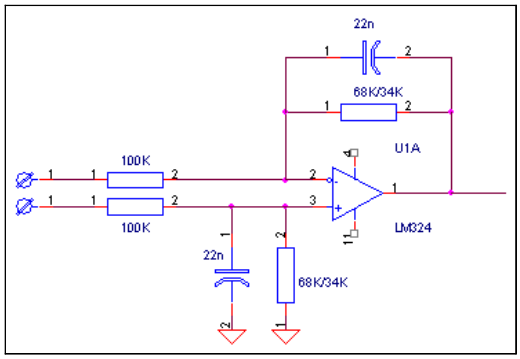
Tachometer input:

In speed mode, the feedback can be gained directly from the Back-EMF, or from a tachometer connected exactly to this input.

The tachometer supply a DC voltage proportional to the speed of the shaft, in order to obtain a greater precision than the Back-EMF feedback.

The input signal must be between -29V and +29V.

The drive configuration, from ModBus, requires to indicate the voltage/speed coefficient (V/Krpm). The drive executes an automatic scaling of the input signal, based on V/Krpm and the nominal parameters, to optimize the resolution of reading.



Attention: if the tachometer output exceeds the range +/-29V, it's necessary to add, *in series to both input terminals*, a resistance of opportune value. The maximum voltage supplied from the tachometer is given by:

$$Vtacho_{max} = VKrpm_{tacho} * Krpm_{max}$$

Note that practically the maximum speed could be over the nominal value, situation in which it is

however necessary to respect the voltage range. The next expression gives the value of the resistance:

$$Rs = \frac{\left[\left(VKrpm_{tacho} * Krpm_{max}\right) - 29{,}4\right]}{\left(\frac{29{,}4}{100000}\right)}$$

The value of Rs is a parameter of the drive configuration.

Jumpers description

Jumper #	ON	OFF
JP1	Test (reserved!)	Normal operation
JP1 + JP2	Test potenza (reserved!)	
JP2	Reset setup to default	
JP3 1-2	Input Pull-Up, NPN mode	
JP3 2-3	Input Pull-Down, PNP mode	

Attention: function marked as 'Test' are reserved to the factory test procedure, **the improper use can seriously damage the drive and/or the motor and cause danger for the operator.**

Modality of operation

The drive controls everytime the current into the motor, realizing a current-loop control. When only this type of control is active, we say that it works in '*current mode'*.

In addition to the current control, the drive can realize a speed-loop control. The feedback can be gained directly from the Back-EMF, or from a tachometer. We call this way of operation 'speed mode'.

Into the current loop we have a PI (proportional-integral) regulator, into the speed loop a PID (proportional-integral-derivative) regulator. In order to obtain the optimal operation of the system, it's necessary to proceed to the calibration of the regulators.

Current mode:

In current mode the drive behaves as a variable current generator. The current that circulates in the motor is proporzional to the reference input signal: a input of 10V corresponds to the nominal current.

The involved options are (make reference to the ModBus datamodel table for details):

Option	Description	Default value	Alternative values
REF	Reference source	Main analog input	RS232 / ModBus
INP	Commands input source	Hardware digital inputs	RS232 / ModBus
LEV	Commands active level	High	Low
ICS	Auxiliary current limit input	Disabled	Enabled
RMP	Current ramps	Disabled	Enabled, configurable duration
FA0 – FA1	Analog input Low-pass filter	Cut at 1KHz	Cut at 1KHz, 500Hz, 200Hz or disabled

The involved parameters are (make reference to the ModBus datamodel table for details):

Name	Reg. #	Unit
Ur	1	V /10
Ic	2	A /10
Ip	3	A /10
Accel	6	s /10
Decel	7	s /10
iPgain	17	Q15
iPgainScale	18	n
iIgain	19	Q15
iIgainScale	20	n
RefDig	21	Q15
VirtualInput	22	bit

Attention: the drive comes with a default calibration of the PI regulator, be careful in modifing this values a little for time. An error could cause dangerous instability.

Attention: it's available a software instrument, running on personal computer with RS232 connection, to make easy access to all options and parameters. It contains also some useful functions of validation.

Speed mode:

In speed mode the drive try to accelerate/decelerate the motor to a speed proportional to the speed setpoint. An analog input setpoint of 10V correspond to the nominal speed.

Under the speed regulation the current control is however active: the drive goes in current limit when the torque remains insufficient to reach the setpoint. The limitation of the current has in first place the scope to protect the motor and the drive from the excessive heating, but also to limit the torque developed in acceleration and deceleration.

The involved options are (make reference to the ModBus datamodel table for details):

Option	Description	Default value	Alternative values
REF	Reference source	Main analog input	RS232 / ModBus
INP	Commands input source	Hardware digital inputs	RS232 / ModBus
LEV	Commands active level	High	Low
ICS	Auxiliary current limit input	Disabled	Enabled
TCF	Feedback type	Back-EMF	Tachometer
RMP	Speed ramps	Disabled	Enabled, configurable duration
FRR	Braking mode	No brake / free-wheel	Ramp or current limit braking
FA0 – FA1	Analog input Low-pass filter	Cut at 1KHz	Cut at 1KHz, 500Hz, 200Hz or disabled
TKO	Tachometer alarm	Disabled	Enabled: open-circuit, short-circuit or reverse connection.

The involved parameters are (make reference to the ModBus datamodel table for details):

Name	Reg. #	Unit
Ur	1	V /10
Ic	2	A /10
Ip	3	A /10
SpeedRPM	4	rpm
RxI	5	Ω x100
Accel	6	s /10
Decel	7	s /10
VKrpm	8	(V/Krpm) /10
Rin	9	Ω x100
sPgain	11	Q15
sPgainScale	12	n
sIgain	13	Q15
sIgainScale	14	n
sDgain	15	Q15
sDgainScale	16	n
iPgain	17	Q15
iPgainScale	18	n
iIgain	19	Q15
iIgainScale	20	n
RefDig	21	Q15
VirtualInput	22	bit

Attention: the drive comes with a default calibration of the PID regulator, be careful in modifing this values a little for time. An error could cause dangerous instability.

Attention: it's available a software instrument, running on personal computer with RS232 connection, to make easy access to all options and parameters. It contains also some useful functions of validation.

RxI compensation

The RxI compensation concurs to correct the voltage fall on the series resistance of the motor, with improved performances using Back-EMF feddback. The series resistance of the motor makes that the voltage applied to the motor is lower. If the resistance is known, this effect is easy to compensate:

$$u_{mot} = uref_{mot} + (RxI * I_{mot})$$

where:

u_{mot} = voltage to the motor
$uref_{mot}$ = reference voltage to the motor

RxI = RxI parameter value
I_{mot} = current to the motor

If "RxI" is 0 this function is disabled.

Attention: the RxI compensation could cause the control to be unstable, be careful in modifing this value a little for time and test the calibration in every load condition.

I^2t protection

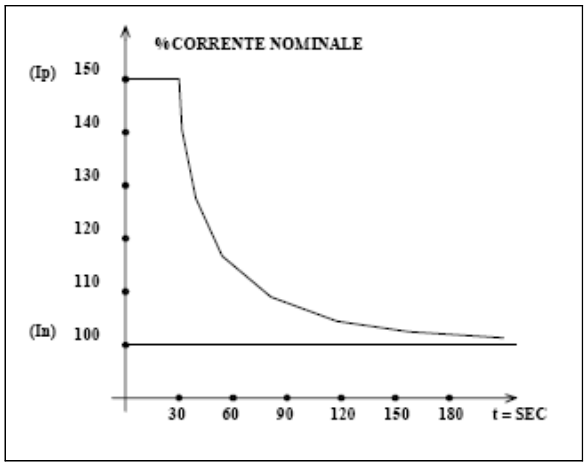
In speed mode, the supplied current can be greater of the nominal value of the motor, the maximum value is fixed from the maximum current parameter. In order to avoid that the motor is overheated because of the greater current, the drive gradually reduces the current until the nomial value: I^2t protection.

The current limitation respects the following rule:

$$\left(I_p - I_c\right)^2 * t$$

where:

Ip = maximum current
Ic = nominal current
t = maximum time at maximum current (2s)



The drive applies the maximum current for the maximum time of 2 seconds. If the current is lower than the maximum, the time admitted for the overload increases. The current is limited gradually until it reaches the nominal value, supplied for a limitless time.

Setting up the same value as nominal and maximum current, I^2t protection is disabled.

Alarms

In alarm case the drive is disabled and it marks the condition with all the LED turned on. Through the ModBus connection, with the configuration software, it's possible to know in the details the alarm cause. In order to restore the operating condition, first you must remove the alarm cause and therefore to turn-off and turn-on the drive.

Alarm	Cause	Solution
Overvoltage	Supply voltage too high.	Use a lower voltage source.
	The voltage grows bacause of the braking action.	Increase the capacitor value on the power supply line. Use a power supply with “braking function”.
Undervoltage	Supply voltage too low.	Use an higher voltage source.
	Power supply capability too low.	Use a 'stronger' power source.
	The acceleration requires a big peak of current that discharge the dc-bus capacitors.	Increase the capacitor value on the power supply line.
Overcurrent	Your motor is a load too big for this drive.	Use a smaller motor or a bigger drive. (if the inductace of the motor is very low, sometimes it's necessary to add an inductor in series to it).
	Machanical load too high.	Reduce the load.
	Acceleration/Deceleration ramps too short.	Increase the duration of the ramp.
Power stage overheating	The drive is too small.	Use a bigger drive.
	Inadequate thermal dissipation.	Verify the coupling of the heatsink, verify if you need a bigger heatsink.
	Load too high.	Reduce the load.
	The acceleration requires a big peak of current that discharge the dc-bus capacitors.	Increase the duration of the ramp.
Power stage shortcircuit	Cable shortcircuit	Replace the cable
	Motor shortcircuit	Replace the motor
	Damaged drive	Replace the drive
Tachometer anomaly	Only with tachometer feedback and tachometer alarm enabled.	Verify tachometer connection and cable.
	Possible causes: tacho disconnected, tachometer (or cable) shortcircuit, reverse connection.	Verify the drive configuration.
		Verify that the tachometer is damaged.
	Attention: when this alarm occurs, the drive switch to Back-EMF feedback mode and disables itself as programmed by configuration (free-wheel, ramp or braking).	

ModBus protocol

The RS232 port allows to configure the drive and to control it from remote.

The serial communication is based on a reduced implementation of the standard ModBus protocol in RTU mode (www.modbus.org).

Only a subset of function is supported:

1. the Rx/Tx buffer is only 50bytes deep, this limits the number of registers for a single transaction, not more than 10.
2. only the following standard functions are supported:

Codice Funzione	Nome Funzione
03h	Read Holding Registers
04h	Read Input Registers
06h	Write Single Register
10h	Write Multiple Register

3. and this user-defined function:

Cod.Funzione	Nome
41h	Request to send a special identification record that contains information about hardware and firmware versions.

The communication port setup is:

Baudrate	19200bps
Byte	8bit
Parity	Even
Stop	1bit

Attention: it's available a software instrument, running on personal computer with RS232 connection, to make easy access to all options and parameters. It contains also some useful functions of validation.

Tabella dei parametri:

Name	Reg. #	Unit	Description
Ur	1	V /10	Motor nominal voltage.
Ic	2	A /10	Motor nominal current. Equal or smaller than the drive nominal current (8A or 5A).
Ip	3	A /10	Maximun current allowed to the motor. Equal or smaller than the drive maximum current (20A or 10A).
SpeedRPM	4	rpm	Nominal speed,. Used when tachometer feedback is enabled, an analog setpoint of 10V correspond to this speed value.
RxI	5	Ω x100	RxI compensation resistance. Used if Back-EMF feedback is selected. Set 0 to exclude RxI compensation function.
Accel	6	s /10	Acceleration time, used only if ramps are enabled.
Decel	7	s /10	Deceleration time, used only if ramps are enabled.
VKrpm	8	(V/Krpm) /10	Speed to voltage coefficient for the tachometer (V/Krpm). This is the nominal transfer gain of the tacho (if you add any resistence indicate the value in reg.#9).
Rin	9	Ω x100	Value of the resistence added (if necessary) to the inputs terminals of the tachomenter.
ConfigFlags	10	bit-field	Option flags: see the specific paragraph that follows.
sPgain	11	Q15	Speed-loop Proportional gain (mantissa, from 0 to +1).
sPgainScale	12	n	Speed-loop Proportional gain scale factor (base 2 exponent, from -8 to +8).

Name	Reg. #	Unit	Description
sIgain	13	Q15	Speed-loop Integral gain (mantissa, from 0 to +1).
sIgainScale	14	n	Speed-loop Integral gain scale factor (base 2 exponent, from -8 to +8).
sDgain	15	Q15	Speed-loop Derivative gain (mantissa, from 0 to +1).
sDgainScale	16	n	Speed-loop Derivative gain scale factor (base 2 exponent, from -8 to +8).
iPgain	17	Q15	Current-loop Proportional gain (mantissa, from 0 to +1).
iPgainScale	18	n	Current-loop Proportional gain scale factor (base 2 exponent, from -8 to +8).
iIgain	19	Q15	Current-loop Integral gain (mantissa, from 0 to +1).
iIgainScale	20	n	Current-loop Integral gain scale factor (base 2 exponent, from -8 to +8).
RefDig	21	Q15	Current or Speed setpoint in 16bit fractional notation. Used when the selected reference source is from ModBus. Values from -1 to +1: 0,75 (24674) is the same of an analog input of 10V.
VirtualInput	22	bit-field	Command inputs, used when the selected commands source is from ModBus. Bit meaning: bit0: disable counter-clockwise rotation bit1: disable clockwise rotation bit2: drive inhibit
ScaleAnRef	29	Q15	This parameter allows to scale main analog input (speed/current reference) by a gain factor from -1 to +1.
OffsetAnRef	30	Q15	This parameter allows to calibrate to zero the offset of the main analog input (speed/current reference).
OffsetAnLim	31	Q15	This parameter allows to calibrate to zero the offset of the auxiliary analog input (variable current limit).

The described parameters reside in the RAM of the drive, a modification can be cancelled simply by turn off the drive. Disable the drive before to modify the setup, the configuration will have effect at the next enable command.

To save permanently the value of a parameter you must copy that value to the register with address $reg.\#_{EEPROM} = 100 + reg.\#_{RAM}$.

Example: to save 2000 to the parameter SpeedRPM ($reg.\#_{RAM}4$) I will send 2000 to the register $reg.\#_{EPPROM} = 100 + 4 = 104$.

The next table shows a list of readonly parameters, useful during the calibration:

Name	Reg. #	Unit	Description
HWLimitV	200	V /10	*Absolute* maximum allowed voltage.
u_dc_busV	205	V /10	Actual DC-Bus voltage (power supply voltage)
a_MotorV	207	V /10	Back-EMF voltage
i_motorA	208	A /10	Current in the motor
prevFault	209	bit-field	Previous alarm flags (when bit is 1): b0=Overvoltage b1=Overcurrent b2=Undervoltage b3=Overheating b4=Shortcircuit b5=Tachometer anomaly

Name	Reg. #	Unit	Description
appFault	211	bit-field	Present alarm flags (when bit is set to 1): b0=Overvoltage b1=Overcurrent b2=Undervoltage b3=Overheating b4=Shortcircuit b5=Tachometer anomaly

About Q15 fractional rapresentation

Parameters defined as Q15 are fixed-point fractional values with 15 bits after the decimal point, that rapresent numbers from -1,0 to +1,0. In order to convert a number from decimal notation to the integer value for the Q15 variable you have to multiply by 2^{15}=32768:

$$Q15 = \frac{dec}{32768}$$

$$dec = Q15 * 32768$$

There are many Q15 parameters that require only positive values, like PI and PID gains.

Configuration flags:

The parameter "ConfigFlags" (reg.#10) contains an array of flags defining the options of the drive. It follows a detailed description of every flag:

ConfigFlags [default 0000h]

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
X	X	X	X	**FA1**	**FA0**	**MOC**	**TKO**	**NAC**	**FRR**	**RMP**	**TCF**	**ICS**	**LEV**	**INP**	**REF**

Option	Description
REF	The speed reference can be supplied through the main analog input, connected to J1 pin 1 and 2, or from serial port with ModBus using register "RegDig". 0 => reference from analog input 1 => reference from ModBus
INP	The commands inputs can be supplied from the hardware inputs, connected to J1, or from serial port with ModBus using register "VirtualInput". 0 => hardware inputs 1 => commands from ModBus
LEV	By default the input are configured as active-high, this option allows to change the active level: 0 => active-high inputs 1 => active-low inputs Attention to the position of JP3 for the insertion of pull-up or pull-down on the input.
ICS	By default the nominal and peak motor currents are defined by registers "Ic" (reg.#2) and "Ip" (reg.#3). This option enables the auxiliary analog input, connected to J1 pin 5 and 6, in order to introduce a variable current limit. In such a case the drive ignores the peak current "Ip" because the motor current will be always limited to a fraction of "Ic" (nominal current), scaled through the analog input where +/-10V=100% and 0V=0%. 0 => "Ic" + "Ip" without variable current limit 1 => "Ic" + with variable current limit
TCF	In speed mode it's possible to select the Back-EMF feedback or the tachometer feedback (connected to J1 pin 3 and 4). 0 => Back-EMF feedback 1 => tachometer feedback

<table>
<tr><th>Option</th><th colspan="3">Description</th></tr>
<tr><td>RMP</td><td colspan="3">Speed mode control and current mode control follow istantaneously every variation of the setpoint. This option introduce the insertion of increment and decrement ramps between the setpoint and the reference of the control loop. In current mode ramps are of current, in speed mode are of speed; in booth cases the registers “Accel” and “Decel” contains the duration time of the ramp, starting from 0 up to 100% (viceversa for deceleration).
0 => ramps disabled
1 => ramps enabled</td></tr>
<tr><td>FRR</td><td colspan="3">At the general inhibit signal the drive can stop the motor in several ways, selected from this option and the RMP.
0 => no brake, free-wheel stop
1 => ramp (RMP enabled) or braking with current limit for a maximum of 2 seconds of time (RMP disabled).</td></tr>
<tr><td>NAC</td><td colspan="3">At the startup, the drive executes a procedure of automatic calibration of the analog inputs of current and voltage of the motor. If this happens while the shaft is completely stopped there is no problem, but if the there is the possibility that the shaft is moving, it's necessary to disable the auto-calibration, exactly with this option.
0 => analog input auto-calibration enabled
1 => analog input auto-calibration disabled</td></tr>
<tr><td>TKO</td><td colspan="3">In speed mode with tachometer feedback, this option enables and disabled the alarm for a tacho anomaly. Tachometer alarm identifies the following cases: tacho disconnected, tachometer (or cable) shortcircuit, reverse connection.
0 => alarm disabled
1 => alarm enabled</td></tr>
<tr><td>MOC</td><td colspan="3">Select the modality of operation, current or speed:
0 => speed mode
1 => current mode</td></tr>
<tr><td>FA1</td><td>FA0</td><td>Frequenza di taglio</td><td rowspan="5">This two bits select the cut frequency of the filter applied to the main analog input, or disable the filter.</td></tr>
<tr><td>0</td><td>0</td><td>1KHz</td></tr>
<tr><td>0</td><td>1</td><td>500Hz</td></tr>
<tr><td>1</td><td>0</td><td>200Hz</td></tr>
<tr><td>1</td><td>1</td><td>disabled</td></tr>
</table>